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FOREST Pest LEAFLET

Introduction to Forest Diseases

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Pacific Forestry Centre

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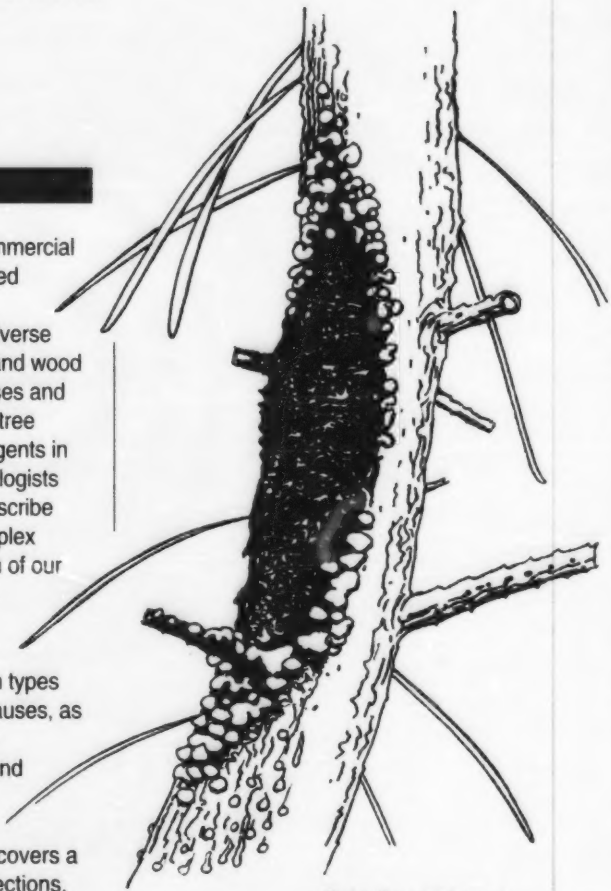
Introduction

The appearance and commercial and recreational use of forested land is greatly affected by diseases, insects, fire, and adverse weather. Of these, diseases and wood decay cause the greatest losses and present the greatest threat to tree growth, outranking all other agents in destructiveness. Forest pathologists conduct research on, and prescribe treatments for, the many complex diseases that affect the health of our forests. This leaflet is a basic introduction to forest pathology. Included here are descriptions of some common types of forest diseases and their causes, as well as an outline of common principles of disease control and investigation.



Stalactiform blister rust - *Cronartium coleosporioides*

The term "tree disease" covers a wide range of pathogenic infections, abnormalities, and disturbances of the normal structure and growth of a tree. Many different species of organisms and non-living agents can cause diseases that may reduce growth, lower quality, kill outright, or predispose a tree to attack by other pests. By definition, "tree disease" refers to the deleterious effects resulting from injurious agents other than fire, insect damage or other types of wounding (e.g. animals or hail).

The causes of tree disease are usually classified as non-infectious or infectious. However, disease symptoms usually develop as a result of a complex interaction between the

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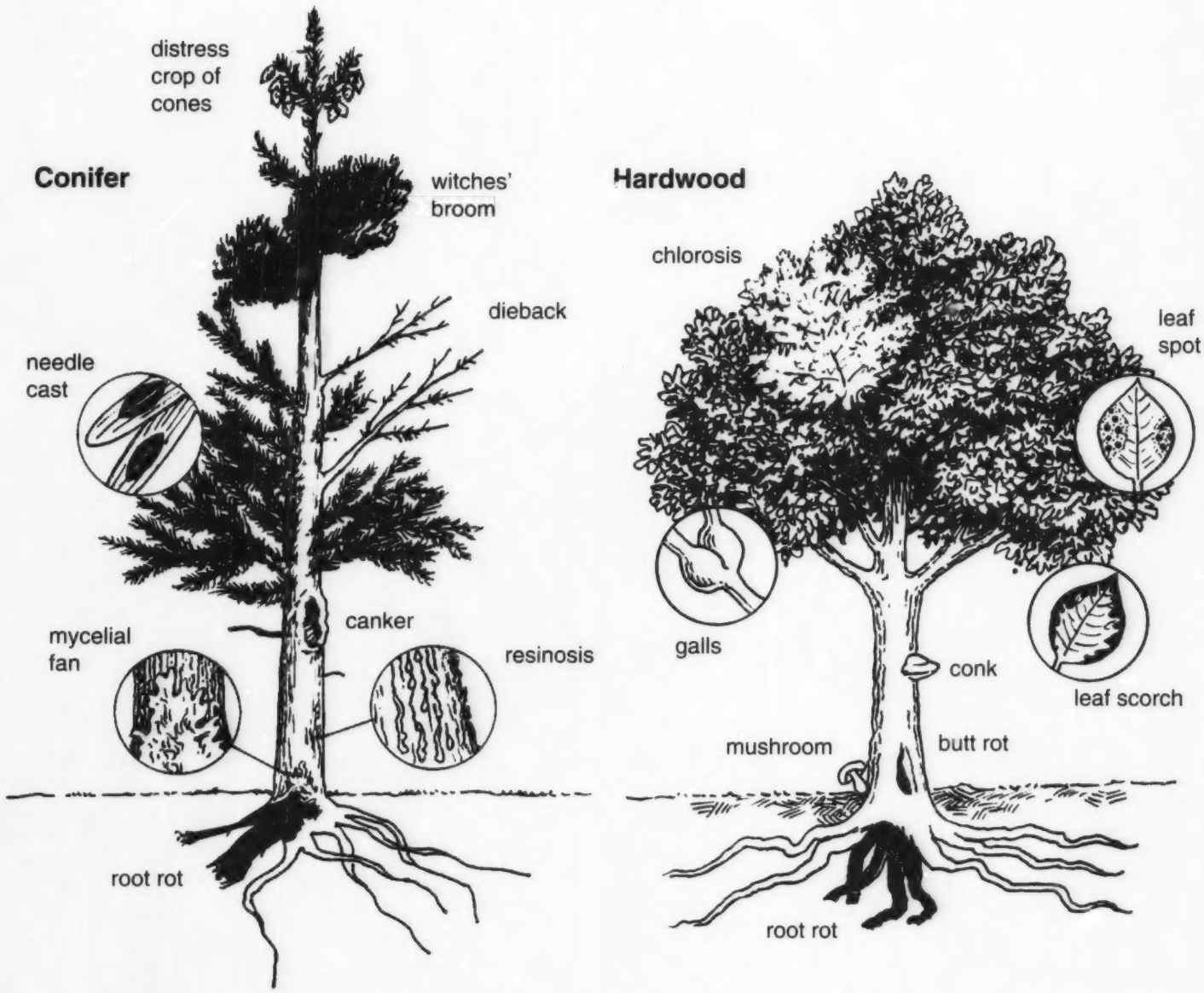


A quick guide to some features of tree diseases

susceptible tree, predisposing environmental conditions, or a living, infectious agent such as a fungus. An awareness of this interaction of living and non-living agents enables greater insight into the dynamics behind disease outbreaks.

In western Canada there are more than 300 species of native pathogenic fungi that are associated with diseases of various species of forest trees. For the most part, they are endemic, causing low, chronic levels of damage throughout the range of their host. Some organisms considered "pests" in stressed trees are in fact acting as culling agents for weakened individuals.

Forestry practices or unusual weather patterns sometimes alter environmental conditions to favor unusually high levels of disease. Accidental introductions of non-native pathogens such as white pine blister rust have in the past caused serious forest disease breakouts because the hosts have not evolved any resistance.

Many common forest diseases in British Columbia are described in greater detail elsewhere in the Forest Pest Leaflet series. These and other forest pathology publications can be obtained from the Candian Forest Service Bookstore at http://bookstore.cfs.nrcan.gc.ca/, or by writing to the address on the last page of this publication.

The technical terms used in this leaflet (identified in **boldface**) are defined in the glossary on pages 14 and 15.

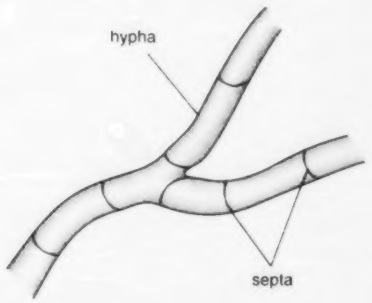
Development of infectious diseases

Living organisms inciting forest diseases are called **pathogens**, and the affected tree is called the **host**. Most pathogens of western trees are **fungi**, but several species of **dwarf mistletoes**, which are flowering plants, also cause serious diseases in trees. A few species of **bacteria**, nematodes (microscopic roundworms), water molds (**Stramenopiles**) and viruses are also known tree pathogens.

Diseases affect the normal function of a tree in various ways. For example, disease-induced defoliation may reduce the amount of food produced by **photosynthesis**. Stem **cankers** weaken the trunk or reduce transport of food to the roots. Root **decay** increases the risk of windthrow, and reduces water and mineral absorption.

To develop successfully a disease requires:

1. A susceptible host: a host that is unable to suppress pathogen development. Seasonal development and tree vigor can affect host susceptibility.
2. A virulent pathogen: a pathogen that has the ability to cause disease and produce **inoculum** (e.g., **spores**) to infect the host.
3. A favorable environment: conditions that are suitable (in terms of moisture, temperature, etc.) and of sufficient duration to allow penetration of the host and subsequent establishment of the pathogen.



Detail of hypha

What are fungi?

Fungi are a distinct kingdom of organisms that are neither plants nor animals. The basic fungal vegetative structure is the microscopic **hypha**, a thread-like tube that may be separated into cells by the formation of cross-walls (**septa**). Unlike plants and animals, fungi absorb all their food from external sources. The hyphae grow through or on their food substrate, and sometimes form a visible (usually whitish) mat called a mycelium. Many fungi are **saprophytic** or **parasitic**.

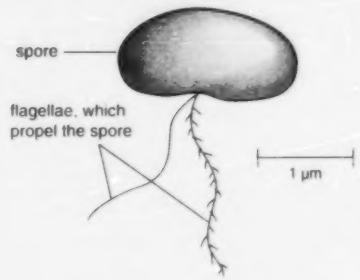
Fungi reproduce by forming specialized cells or groups of cells called spores. Spores may be borne directly on a hypha (i.e., molds). Other fungi disseminate their spores from specialized mycelial structures, called **fruit bodies**, which are extremely diverse in shape and size (see illustrations on page 5). Fruit body types include mushrooms, bracket fungi, discs, cups, minute flask-like **perithecia**, and **pycnidia**, to name a few. They are formed either as a means of **sexual reproduction**, or simply **vegetatively** under the right conditions. The morphology of fruit bodies – and particularly how the spores are borne – is one of the bases of classification of fungus classes associated with tree diseases.

An overview of fungus classes associated with tree diseases

One group of fungus-like organisms and three main groups of fungi are associated with diseases of forest trees. These groups are described in the following overview, and specific disease examples are described in a later section. Generally, the type of disease is characteristic of the group of organisms: for instance, bracket fungi and mushrooms are usually associated with wood and root decay. Some exceptions and overlaps are noted.

1) Water molds: Oomycetes

The **Oomycetes** are microscopic soil and water organisms which were formerly classified as fungi but are now placed in a group known as the **Stramenopiles**. They differ from true fungi in cell wall composition and features of the motile swimming spores. They are more closely related to the brown algae and diatoms than true fungi. In forestry, some species are associated with diseases of roots, especially of seedlings. Fruit bodies are too small to see with the unaided eye. The asexual spores, called **zoospores**, are motile and aquatic and are produced inside structures called **sporangia**. Water is required for their dissemination. The sexual spores, **oospores**, are thick-walled and non-motile. Diagnosis of water mold root rots and damping-off caused by Oomycetes usually requires laboratory culturing techniques and the use of a microscope.



Motile spore (zoospore) of an Oomycete

2) Sac fungi and molds: Ascomycetes and Mitosporic Fungi (formerly called Deuteromycetes, or Fungi Imperfecti)

The **ascomycetes** (see illustrations, facing page) produce their sexual spores in sacs known as **asci**. The asci, which usually contain eight **ascospores**, are usually produced in fruit bodies (such as flask-shaped **perithecia** or cup-shaped **apothecia**) that range from microscopic to large discs up to 15 cm in diameter. Ascospores, which are often released by an explosion of the ascus, become wind-borne. Many ascomycetes also produce an **asexual** (**conidial**, or **mitosporic**) spore stage that is known as the **anamorph**. The anamorph usually occurs as a mold-like growth before development of the sexual stage, or **teleomorph**. Frequently only the anamorph occurs in nature. When the teleomorph is unknown they are grouped in an artificial assemblage called **mitosporic fungi** (former names include Deuteromycetes and Fungi Imperfecti). **Conidia** of mitosporic fungi are produced on specialized hyphae called **conidiophores**, which may develop in specialized fruit bodies, such as **pycnidia**. Diseases incited by these fungi are mostly **cankers**, leaf **blights**, **needle casts** and vascular wilts (clogging and damaging of conductive tissues).

3) Mushrooms and conks: Hymenomycetes (Holobasidiomycetes)

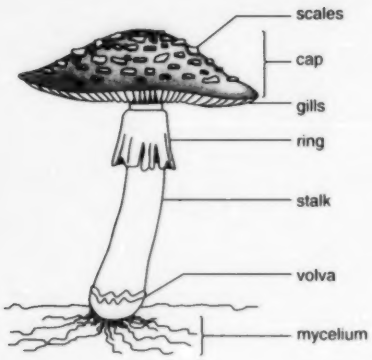
Examples of **hymenomycete** fruit bodies are the familiar mushroom, and the bracket fungus. All hymenomycetes, which are members of the phylum Basidiomycota, are characterized by microscopic, usually club-shaped, one-celled **basidia**. Basidia cover the surfaces of mushroom gills, bracket fungi pores, and other **fruit bodies**, collectively producing millions of **basidiospores**. Examples of some of these structures are illustrated on the facing page. Many of these fungi commonly cause wood decays and root rots. Mushrooms which fruit under forest trees are a common sight. Many species of mushrooms are not **pathogens**, but in fact benefit trees. Their **mycelium** forms a symbiotic association with tree roots, helping the roots absorb water and minerals for the tree. These fungus-roots are called **mycorrhizae**.

4) Rusts: Urediniomycetes (Basidiomycota)

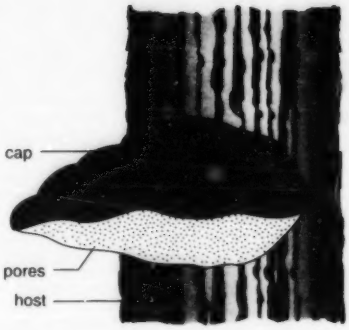
The **Urediniomycetes** (see pages 9 to 11 for illustrations), or rusts, form a unique group of **obligate parasites**. Many rust fungi complete their life cycle on two unrelated host plants. They produce up to five different spore states, one of which (the thick-walled overwintering **teliospore**) germinates to form a **basidium**. Each spore state can differ notably in appearance from others, so the same disease may look different depending on which spore state is currently being produced. Microscopically, the basidia of rust fungi differ from hymenomycetes in that they are usually four-celled. The name "rust" describes the characteristic **sign** of these pathogens: infected areas of the host are often covered with conspicuous rusty orange to yellow masses of loose spores. Some rusts produce blister-like **cankers** on stems; others attack only the needles, leaves or cones of trees.

Fungus Anatomy

Mushrooms and Conks
(Holobasidiomycetes)

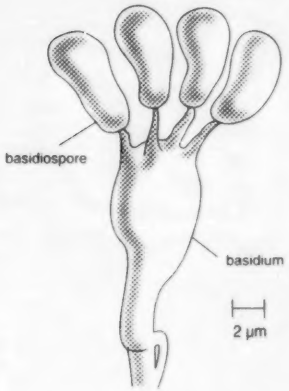


Mushroom



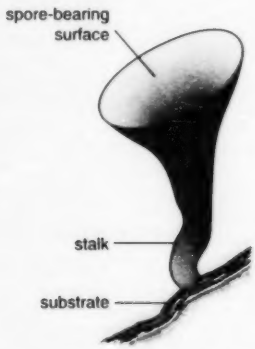
Conk (bracket fungus)

microscopic features

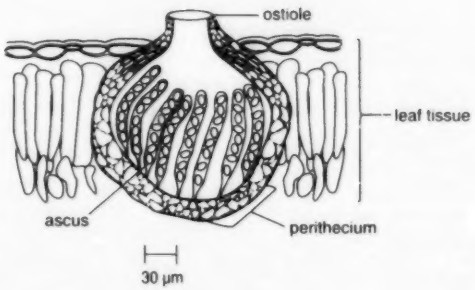


Basidium

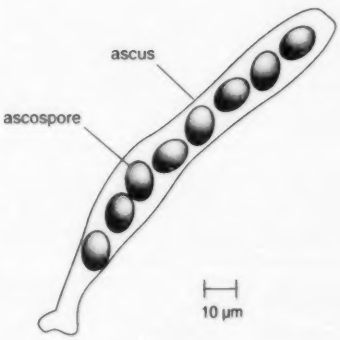
Sac Fungi
(Ascomycetes)



Apothecium of a cup fungus (actual size)

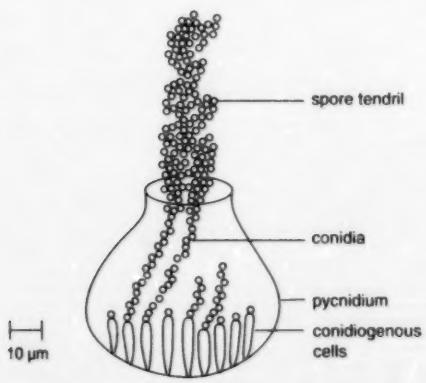


Perithecium of a leaf spot fungus

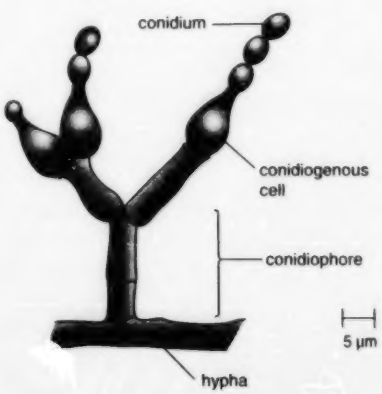


Ascus

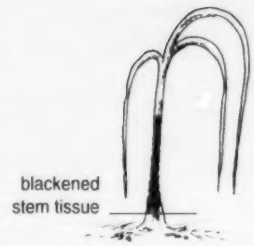
Conidial states of Ascomycetes



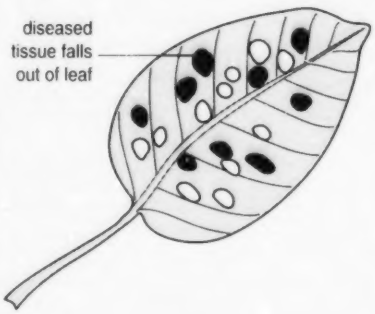
Pycnidium



Conidiophore



Damping-off symptoms on a conifer seedling



Shot-hole symptoms in a leaf

Blight symptoms

Examples of diseases caused by fungi

1. Diseases caused by water molds (Oomycetes)

Water molds cause root rot in conifers and **damping-off** of their seedlings. Two genera of fungi are often associated with these diseases. Damping-off is often associated with *Pythium* under certain conditions of poor drainage. The bark tissue of the roots of certain conifers is susceptible to rotting caused by *Phytophthora*. Disease symptoms are usually most severe under conditions of poor drainage.

2. Diseases caused by sac fungi and molds (Ascomycetes and mitosporic fungi)

Leaf spots and anthracnoses

The foliage of broadleaf trees is subject to a great variety of fungi that kill part or all of the leaf. Occasionally early defoliation results. The **necrotic** spots are sometimes sharply delineated and often round when first developing. Some fungi produce a black **sclerotium** (or tar spot) in the leaf that may fall away leaving a "shot-hole."

Needle casts and blights

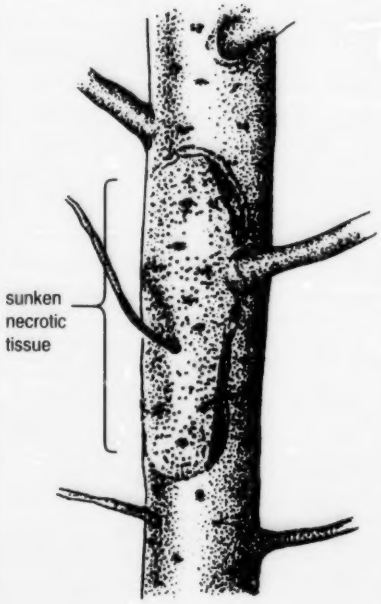
Needle cast fungi infect only young, developing needles of the current year, but **needle blights** may occur on any age of needles. Often these diseases take longer than a year to manifest symptoms. There is usually little evidence of attack during the year of infection while the fungus grows vegetatively in the needle tissues. In the following year, yellowing or reddening of infected needles occurs and fruit bodies may appear in these discolored areas. Frequently the needles are cast after spore discharge, but in some types of needle blights the dead foliage remains on the tree for abnormally long periods. The ascomycetes *Lophodermella concolor* and *Lophodermella montivaga* are responsible for widespread needle cast of 1-year-old foliage of lodgepole pine. Another ascomycete, *Lirula macrospora*, causes needle blight of spruce.

Needle cast symptoms and signs

Cone, seed and seedling diseases

Several fungi either damage cones, kill the seed, or are seed-borne, attacking seedlings that emerge at germination. The **mitosporic fungus** *Sirococcus strobilinus*, for example, is seed-borne, infecting the seed cones of many conifers and producing **pycnidia**, which ooze slimy **conidia** that stick to the seeds. The fungus does not kill the seed, but may infect and kill the germinant when it emerges. The ascomycete *Caloscypha fulgens* infects conifer seed cones that fall to the ground. Its hyphae penetrate the seed coat and destroy the seed. In the spring, large orange cup-shaped apothecia are produced above the buried seeds.

Target canker symptoms on *Prunus*



Phomopsis canker on Douglas-fir

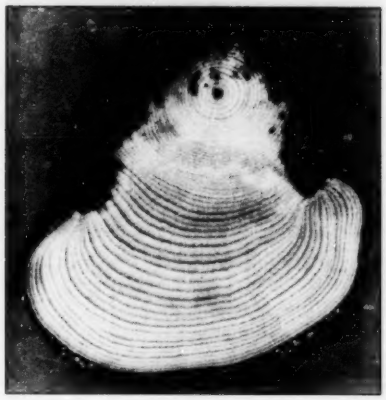
Cankers and diebacks of bark

A **canker** is a localized **lesion** or area of **necrosis** on stems or branches. Three general types of cankers may be encountered on trees:

1. Perennial or **target cankers** are circular to lens-shaped and may include **callus** tissue (usually in concentric ridges) at the face or margins. The canker expands slowly, roughly equaling the radial growth of the tree. A target canker commonly seen on native *Prunus* is caused by the ascomycete *Tympanis* sp.

2. **Diffuse cankers** grow more rapidly than the radial growth of the tree and so include little or no callus. They usually girdle the tree after several years. A diffuse, sooty-bark canker of aspen is associated with the ascomycete *Encoelia pruinosa*.

3. Annual cankers or **canker blights** develop rapidly for one season only and contain little or no callus. They frequently occur on stressed trees that have been predisposed by frost, drought, or physical damage. Annual cankers of Douglas-fir are caused by the ascomycete *Diaporthe lokoyae* (anamorph = *Phomopsis lokoyae*) in times of water stress or frost damage. The dead bark is overgrown by callus in the following growing season, however, and complete healing can result. If the canker fungus also invades the underlying wood, **canker rot** is produced. One example is Atropellis canker of lodgepole pine, a perennial canker caused by the ascomycete *Atropellis piniphila*. Atropellis cankers are usually large, sunken, and resin-soaked with a bluish-black stain of the underlying wood. Black disc-like apothecia 2-3 mm in diameter develop on the cankers.



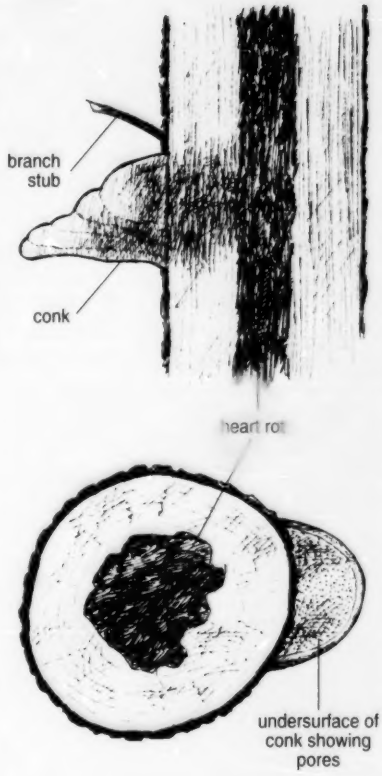
Transverse section of stem with Atropellis canker rot.

Root rots

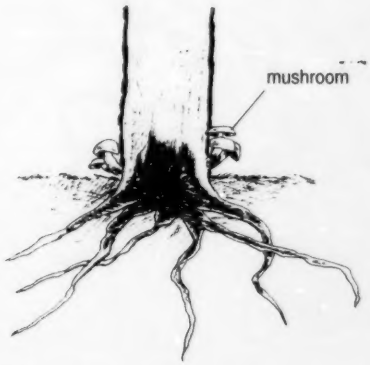
In the nursery, species of *Fusarium*, *Phoma* and *Cylindrocladium* are associated with the damping-off and dieback of seedlings. These fungi are **mitosporic fungi**, the anamorphs of **ascomycetes**. *Rhizina undulata* is an ascomycete that attacks conifer seedlings planted in recently burned areas. It produces a very large black disc-shaped fruit body (apothecium) around dead seedlings and burned woody debris.

Wood stains

Certain deep-seated stains in wood indicate the incipient stage of decay. Other stains are caused by ascomycetes that do not break down the wood appreciably but may lower its commercial value. **Blue sapwood stain** is an example of the latter case.



Heart rot, and conk developing at a branch stub



Armillaria root rot and butt decay

3. Diseases caused by mushrooms and conks

Wood decay of stems

Mostly caused by mushrooms and **conk**-producing fungi, stem decays are classified as **heart rots** or **sap rots** on the basis of the type of wood colonized. In living trees, most decay fungi colonize the **heartwood**. Some, however, may decay both heartwood and **sapwood** and a few fungi attack only sapwood. Most sapwood decays occur in recently felled trees. In general, the fungus breaks down the bond between the lignin and cellulose components of wood and uses them in its growth. Fungi that use only cellulose cause **brown cubical rots**; the name aptly describes the remaining wood, which is high in lignin. Fungi using both lignin and cellulose cause **white rots**, so called because the remaining wood, which has a high cellulose content, is light in color. White rots may be stringy, laminated, pitted, or mottled depending on the species of fungus involved, but they are never cubical. Decay fungi gain access to the heartwood or sapwood through damaged bark, broken branches and tops, and roots. Infection can be caused by airborne spores or by the spread of mycelium underground from a nearby infected tree, through root contact or special fungal structures such as the shoestring-like **rhizomorphs** of *Armillaria* (a root and butt-rot mushroom). Decay fungi normally develop slowly and rot may be present in a tree for many years or decades before the spore-producing **conks** or mushrooms appear. The presence of conks is thus often a **sign** of advanced decay in the tree. As long as the conditions for fungal growth are favorable, the process of decay is continuous. Those favorable conditions include appropriate temperature, moisture, oxygen, and nutrient levels.

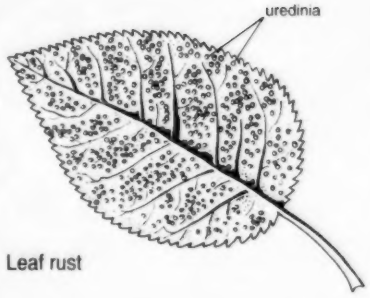
Root rot and stump infections

Certain basidiomycetes, such as *Phellinus weirii,* colonize large roots of mature conifers decay the wood, and kill living roots, resulting in tree mortality. The fungus spreads to other trees by root contact and establishes a disease centre (area of dead and dying trees) in the stand. Affected trees often have deteriorating crowns, distress cone crops, and are subject to windthrow. Even after trees are cut down, the fungus remains alive in the dead roots and may perpetuate the disease to future rotations. The spores of other root rot fungi, for example, *Heterobasidion annosum*, can colonize the freshly-cut stumps of healthy conifers and establish themselves in the dead roots from where the fungus can spread via grafting to healthy trees. For this reason, stump treatments are used during commercial thinning to either kill pathogenic fungi or encourage other, non-pathogenic decay fungi, which compete with and thus prevent the development of pathogenic fungi.

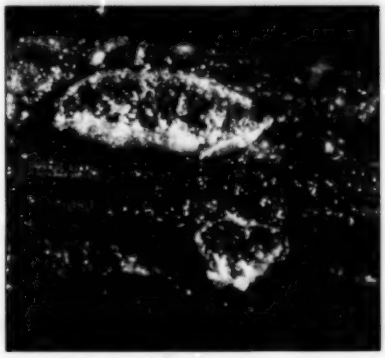
Wood decay of dead timber and slash

Decay of slash and wood debris in a forest ecosystem is not considered a disease, but rather an important process in recycling forest elements to the soil. Brown rotted wood is a major component of forest soils. In addition, many cavity-nesting birds and animals rely on hollows and soft pockets of wood decoy to build nests in trees, snags and stumps.

However, fungal decay of wood used in construction is a concern. Some tree species are more resistant to decay than others (for example, western redcedar is more durable than Douglas-fir) and exposed sapwood is less resistant than heartwood. Moisture is a critical factor; approximately 25% water content or more is required for decay to proceed. The majority of serious wood decay fungi are basidiomycetes.



Leaf rust



Aecia of the fir-willow rust (*Melampsora abieti-capraearum*) on the underside of an alpine fir needle

Needle rust

4. Diseases caused by rusts (Urediniomycetes)

The rusts are **obligate parasites** that often have a complex life cycle (see illustration on page 10) generally requiring two unrelated (**alternate**) hosts (such as a tree and a herbaceous plant) for completion. Two types of spore-producing structures (**spermagonia**, and **aecia**) are produced on the **aecial host** and three types of spore-producing structures (**uredinia**, **telia**, and **basidia**) occur on the **telial host**. A **host-alternating** rust is termed **heteroecious**. Some rusts complete their life cycle on a single host; these are called **autoecious**. The aecial host of heteroecious tree rusts is usually a conifer, but there are exceptions. To make matters even more complicated, not all types of spores are produced by every rust; some have reduced life cycles.

Leaf and needle rusts (for example, *Melampsora* and *Pucciniastrum*)

A typical foliar rust life cycle is illustrated on page 10. Most foliage rusts are **host-alternating**. Because the aecial host is more frequently a conifer, the **spermagonial** and **aecial states** are both found on needles. Spermagonia appear in spring as inconspicuous spots that exude **spermatia** in droplets of sweet liquid. Insects spread spermatia to adjacent spermagonia, where they fertilize receptive hyphae. Aecia form soon after at the same site and are conspicuous white, yellow, or orange structures with masses of aeciospores. **Aeciospores** can only infect the non-coniferous telial host.

On the leaves of the telial host (fireweed, for instance), uredinia develop as cream-colored pustules that produce **urediniospores**. This spore stage quickly spreads the rust on the telial host, as it infects, grows and sporulates in several cycles over the same season. Telia develop in the place of uredinia in late summer and the **teliospores** either germinate in the same summer or overwinter. On germinating, the teliospore produces a basidium, which in turn produces four **basidiospores**. The basidiospores infect only the coniferous aecial host.

Leaf and needle rusts are most damaging to young trees because premature defoliation may weaken the tree in this crucial stage of growth.

Cone rusts (*Chrysomyxa*)

Spruce cone rusts are economically important diseases in British Columbia, particularly in seed orchards. When **aecia** are produced on the cone scales, the whole cone — including the seeds — may be destroyed or seed germination may be reduced. **Resinosis** can hinder dispersal or extraction of seeds from the cones.

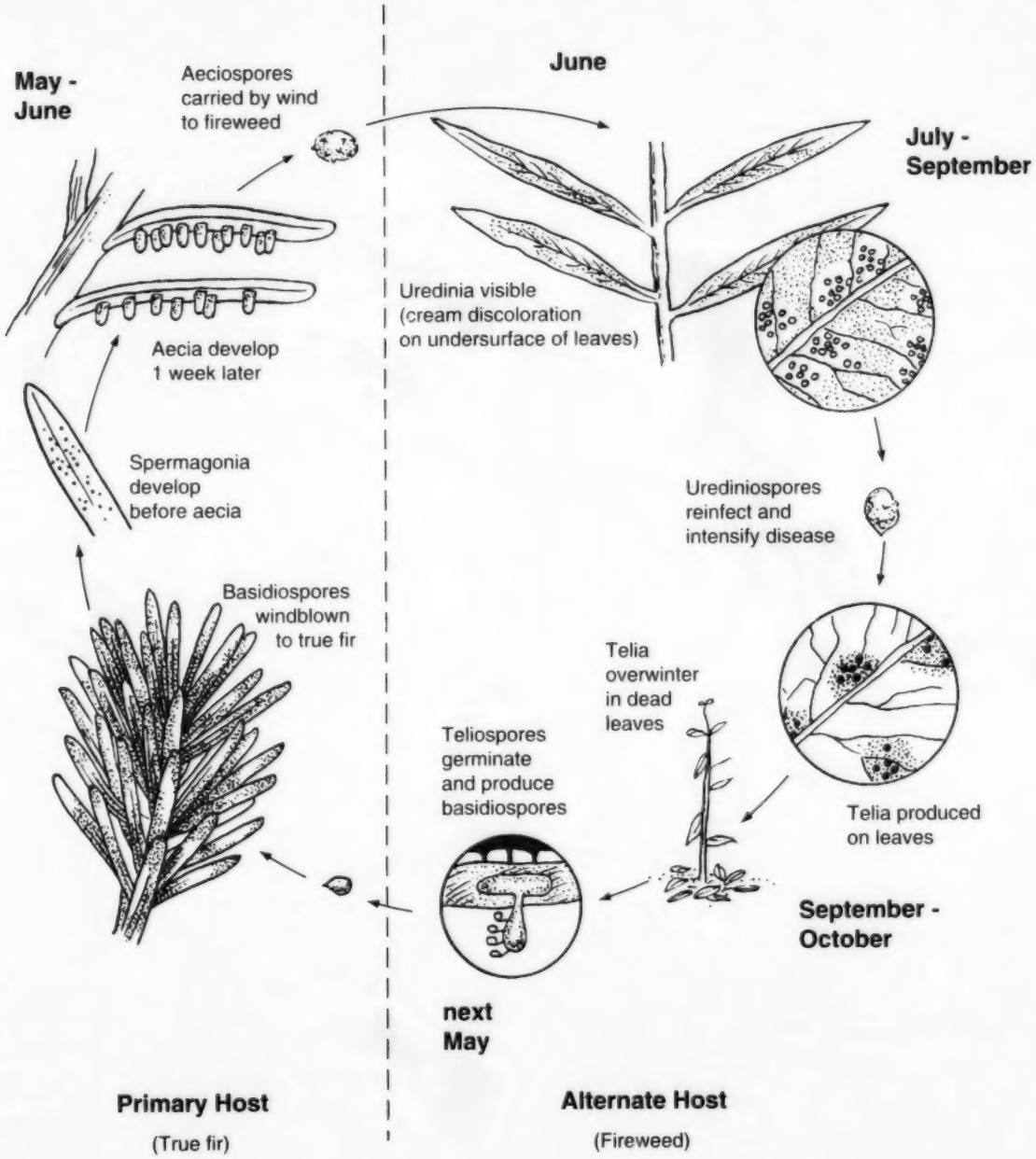
Alternate hosts (producing telia) of the cone rust are inconspicuous flowering plants (for example, *Moneses* and *Pyrola*).

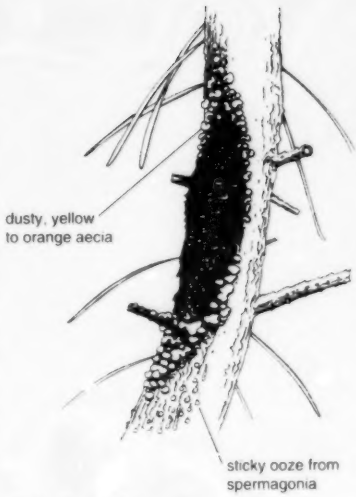
Stem rusts (*Cronartium*)

Stem rusts, which are among the most destructive forest pathogens, occur only on pines. The large blister-like cankers or the **galls** they produce weaken and may eventually kill the tree.

White pine blister rust, caused by *Cronartium ribicola*, has essentially eliminated white pine as a usable species in B.C. Its alternate host may be one of several species of currants and gooseberries (*Ribes*). The large, orange aecial blisters appear on the pine in the spring and release aeciospores, which the wind carries to the *Ribes* leaves. This is not a native pathogen, but was introduced around 1910 on imported pines from Europe.

An Example of a Rust Life Cycle
(fir-fireweed rust)





Stalactiform blister rust
Cronartium coleosporioides

Gall rust

Aerial shoots of lodgepole pine dwarf mistletoe

Broom rusts (for example, *Chrysomyxa* and *Melampsorella*)

Conspicuous, yellowish-orange **witches' brooms** are produced in spruce trees by the fungus *Chrysomyxa arctostaphyli*. The aecial pustules develop in the broom on current-year needles, which turn yellow and are shed in the fall. Because the rust develops into a **systemic infection**, new needles in an established broom always produce aecia each year. **Hypertrophy**, dead branches, bole deformation, and increment loss result. The alternate host is the common bearberry (*Arctostaphylos uva-ursi*). *Melampsorella caryophyllacearum* causes brooms of the true firs (*Abies* spp.). The alternate host is chickweed (in the family Caryophyllaceae).

Witches' brooms

Galls

Some rust fungi (and some ascomycetes, too) cause hypertrophy and **hyperplasia** of stem tissue, which results in swollen areas called **galls**. Western gall rust, *Endocronartium harknessi*, is common on stems and branches of lodgepole pine. Many galls are also caused by insects and bacteria.

Viruses, bacteria and mycoplasma-like organisms

These three groups of submicroscopic to microscopic organisms are important in plant and tree diseases in many parts of the world. In western Canada, however, none of these are currently associated with a major forest tree disease. A rare gall disease on stems of Douglas-fir is caused by a soil-borne pathogenic **bacterium**.

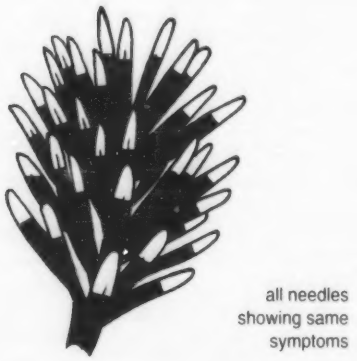
Disease caused by dwarf mistletoes

Dwarf mistletoes (*Arceuthobium* spp.) are parasitic plants that can cause severe swelling, brooming, and deformation of conifers. The germinating dwarf mistletoe seed produces a root capable of penetrating the bark and growing into the **phloem**. Later, parts of this root system become embedded in successive layers of wood. Infections are perennial and after 2-5 years the plants produce conspicuous male and female **aerial shoots**. The seeds, produced by the aerial female shoots, are sticky and forcibly ejected to distances up to 7-10 m.

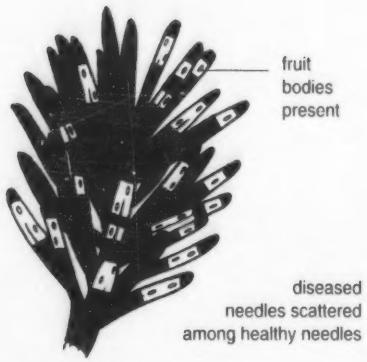
Non-infectious agents of disease

Non-living stress factors can also injure and kill trees. Mostly these are meteorological extremes affecting temperature and moisture, but human-caused problems such as air pollution also cause tree disease. As a rule, **symptoms** of non-infectious diseases are uniform on the entire tree, or increase in intensity closer to the source of emission in the case of pollution, while symptoms of infectious diseases are variable and more random.

The general decline of forest vigor in many parts of the world is now attributed to "acid rain," the deposition of sulphur dioxide and other pollutants from industrial air pollution.



Non-infectious disease symptoms



Infectious disease symptoms

Direct fume damage to foliage may also occur in the vicinity of smelters and pulp mills. The symptoms are yellowing and withering of the leaves and, if repeated year after year, damage leads to dieback of branches.

Occasionally herbicides, other pesticides, and fertilizers cause leaf damage, defoliation, and tree mortality. Early symptoms of injury may be expressed through twisting, other deformation of foliage, or discoloring of leaf margins on sensitive plants.

Frost and cold weather are serious causes of damage to trees in Canada. A late spring frost may kill newly flushed shoots and leaves, whereas an early autumn frost may damage bark that has not hardened for the winter. Winter flecking of needles is frequently mistaken for infectious needle cast diseases.

"Red belt," or winter drying, is a needle discoloration that affects large tracts of coniferous forests in a specific altitudinal zone. The affected trees, which have reddened foliage, occur in long, narrow, horizontal "belts" on a mountainside. Tree mortality has resulted from these occurrences which are associated with warm winds in winter. The condition was once explained as resulting from increased transpiration when the ground was frozen, resulting in desiccated needles, but is now thought to be caused by a rapid drop in temperature following a thaw.

Sunscald is heat injury to bark and **cambium** resulting from the direct exposure of young trees to intense sunlight. Cankers, pitch blisters, and open wounds may occur where the bark is killed.

Non-infectious diseases such as winter drying, late frosts and air pollution often produce symptoms that may be confused with foliar diseases caused by fungi. The environmental diseases may be distinguished from infectious diseases by the absence of fruit bodies and the lack of randomness characteristic of infectious needle diseases (healthy needles scattered among diseased ones - see illustrations above).

Principles of control of forest diseases

There are many diseases in the forest for which no control measures have been devised, or for which control is neither logistically nor economically feasible on a large scale. Diseases that are amenable to treatment, however, have been controlled with the following measures:

- **Proper site selection**

  Correct site selection for planting will minimize damage from most native diseases in a stand by promoting good growth and natural **resistance**.

- **Forest management**

  Practices such as thinning, pruning, and cutting can be used to control certain diseases. Dwarf mistletoe control, for example, depends almost entirely on harvesting methods (see Forest Pest Leaflet No. 44).

- **Direct control**

  Infection can be prevented and residual disease centres eliminated by measures such as the application of fungicides, stump treatment after felling, and removal of diseased stumps. All of these treatments are used to control root disease.

- **Quarantine**

  Legally restricting the movement of trees from a diseased area to disease-free areas is a means of preventing introduction or controlling the spread of a pest.

- **Breeding for resistance**

  Selection of trees that show resistance to disease and use of resistant trees in breeding programs offers hope that some pest problems may be genetically overcome.

Principles of forest pathology

Greater understanding of forest disease syndromes often involves much painstaking study. Complicating factors such as predisposing weather, **secondary fungi** and genetic variation in a single species of fungus or host, require that each step of an investigation be carefully undertaken according to scientific principles. The following aspects of a pathogen and techniques used in its study are important to forest pathology research:

• Culturing - the suspected pathogen should be obtained in a pure, artificial culture, where possible.

• Pathogenicity study - according to Kochs' Postulates (see below), the organism should be proven to be the cause of an infectious disease.

• Life cycle - all spore states should be identified and studied and related to host range and **phenology**.

• Conditions for infection - the general physiology and requirements for spore germination, penetration, and so on should be elucidated.

Rules of Proof (Koch's Postulates)

1. Show constant association of the organism with the disease.
2. Isolate the organism in culture from the diseased plant.
3. Inoculate a healthy plant from the culture and produce the same disease.
4. Re-isolate the same organism from inoculated plants.

Information available on the World Wide Web:

Common Tree Diseases of B.C.
http://www.pfc.cfs.nrcan.gc.ca/diseases/CTD/index_e.html

Specimen collection:
http://www.pfc.cfs.nrcan.gc.ca/biodiversity/herbarium

Submitting disease samples

The Pacific Forestry Centre Herbarium accepts identification requests on a limited basis, if the collections pertain to forest pathology or biodiversity research on forest fungi in B.C. If collections are from the Victoria area, please contact the herbarium directly (see telephone, facsimile, numbers, street and email addresses on the back page of this Pest Leaflet) prior to sending samples. Outside the Victoria area, the Regional Pathologist of the B.C. Ministry of Forests may also be contacted for disease collection slips, and a referral.

In order to make a proper diagnosis, forest pathologists require accurate field collection information, and a viable, representative collection of diseased material. Minimal data and specimen collection standards requested by all plant pathologists are described below.

Collection data must include the following:
1. date and location of collection
2. species, age, and condition of the host, including any symptoms not present in the material collected
3. complete name, address and telephone number (as well as FACs number and email address, if available) of the collector
4. observations and other comments (e.g., stand treatments)

Samples should be representative of the disease symptoms and big enough to be dissected or cultured if necessary. Any fungus fruit bodies present, such as conks or mushrooms, should also be included, but the latter should be packaged in such a way that they are not damaged in transit by accompanying wood samples. Samples should be wrapped in paper in a protective container, but not in plastic bags which encourage mold growth and deterioration. Diseased foliage should be pressed between sheets of newspaper before being shipped. Samples to be used for culturing should be wrapped in paper towels and then placed in plastic bags if there is a danger of them drying out, but they must be shipped quickly, or they will become contaminated with surface bacteria and molds. Wood decay samples should be large enough to split with an axe, and preferably should contain areas with both early and advanced signs of decay.

Selected references

Allen, E.; Morrison, D.; Wallis, G. 1996. Common tree diseases of British Columbia. Canadian Forest Service, Pacific Forestry Centre. 178 p.

Boyce, J.S. 1961. Forest pathology. 3rd ed. McGraw-Hill, New York, N.Y. 572 p.

Funk, A. 1981. Parasitic microfungi of western trees. Canadian Forestry Service, Pacific Forestry Research Centre, Information Report BC-X-222. 190 p.

Funk, A. 1985. Foliar fungi of western trees. Canadian Forestry Service, Pacific Forestry Research Centre, Information Report BC-X-265. 159 p.

Hiratsuka, Y.; Langor, D.W.; Crane, P.E. 1995. A field guide to forest insects and diseases of the prairie provinces. Canadian Forest Service, Northwest Region, Northern Forestry Centre, Special Report 3. 297 p.

Holliday, P. 1989. A dictionary of plant pathology. University Press, Cambridge. 369 p.

Malhotra, S.S.; Blauel, R.A. 1980. Diagnosis of air pollutant and natural stress symptoms on forest vegetation in western Canada. Canadian Forestry Service, Northern Forest Research Centre, Information Report NOR-X-228. 84 p.

Sinclair, W.A.; Lyon, H.H.; Johnson, W.T. 1987. Diseases of trees and shrubs. Cornell Univ. Press, Ithaca, N.Y. 574 p.

Whitney, R.D.; Hunt, R.S.; Munro, J.A. 1983. Impact and control of forest disease in Canada. For. Chron. 59:223-228.

Ziller, W.G. 1974. The tree rusts of western Canada. Dep. Environ., Can. For. Serv. Publ. No. 1329. 272 p.

A short glossary of forest disease terms

Aecial host: the host on which the spermagonial and aecial states of rusts develop.

Aecial state: the second spore stage in the life cycle of rust fungi producing aeciospores.

Aeciospore: rust spore formed in an aecium.

Aecium, pl. **Aecia:** a cup or tube-like fungal structure which produces chains of aeciospores.

Aerial shoot: stem-like portion of dwarf mistletoe plant outside the host bark. Its primary function is reproduction.

Alternate host: term used to describe other plant species which can be host to the same pathogen. When used with respect to rusts, it usually refers to host(s) supporting different (i.e. aecial vs telial) spore stages.

Anamorph: the asexual (conidial) form of a fungus.

Apothecium, pl. **Apothecia**: cup-like fruit body of ascomycetes

Ascomycetes: a biological grouping of fungi (the sac fungi) typified by the ascus within which typically eight ascospores are produced

Ascospore: sexual spore produced in an ascus.

Ascus, pl. **Asci**: a microscopic sac-like structure containing ascospores.

Asexual reproduction: reproduction not involving nuclear fusion.

Asexual state: see anamorph.

Autoecious: rusts completing the life cycle on one host (cf. heteroecious).

Bacterium, pl. **Bacteria:** one-celled prokaryotic microorganisms which have no chlorophyll but have cell walls, and multiply by simple division.

Basidium, pl. **Basidia:** a microscopic spore-bearing structure composed of one or several cells which typically produces four basidiospores externally on the surface.

Basidiomycetes: a biological grouping of fungi (mushrooms, bracket fungi, and rusts) characterized by production of sexual spores on a basidium.

Basidiospores: sexual spores produced on a basidium.

Biological control: the control of a pest by other living organisms such as viruses, fungi, bacteria or insects.

Blight: sudden drying and browning involving whole organs such as fruits, blossoms, leaves, twigs, and shoots.

Blue sapwood stain: a deep-seated blue (sometimes more blackish or gray) discoloration confined mostly to sapwood, caused by fungi.

Brown cubical rot: a wood decay in which the causal fungi decompose more cellulose than lignin. The brittle, brown, lignin-rich residue breaks into cubes in the advanced stage of decay.

Callus: host tissue that develops at the margins of wounds or cankers.

Cambium: the actively dividing layer of cells that lies between xylem and phloem tissues in higher plants.

Canker: an area of diseased tissue, often sunken, on a living stem or branch.

Canker blight: cankers that develop for one season only.

Canker rot: cankers that extend to underlying wood, and cause its decay.

Chlorosis: yellowing of normally green tissue owing to subnormal chlorophyll content.

Conidiophore: a specialized hypha that bears conidia.

Conidium, pl. **Conidia:** an asexual spore usually formed on a specialized hypha (conidiophore) or in a pycnidium.

Conk: a term often used to describe fungus fruit bodies occurring on wood (i.e. a polypore).

Damping-off: disease of seedlings associated with withering and decay of roots and stem.

Decay: the process by which sound plant tissue (i.e. wood) is degraded by the action of fungi and other micro-organisms.

Deuteromycetes: see Mitosporic Fungi.

Diffuse cankers: cankers containing little or no callus.

Dioecious: unisexual, with the male and female elements in different individuals.

Dwarf mistletoes: flowering plants. (*Arceuthobium* spp.) parasitic on conifers, often associated with cankers and witches brooms.

Fruit body: a fungus structure specialized for producing spores, for example, conk, mushroom, apothecium and pycnidium.

Fungus, pl. **Fungi:** a kingdom of parasitic, saprophytic, or symbiotic eukaryotic organisms made of cellular filaments known as hyphae. Fungi feed by absorption and reproduce by forming spores.

Gall: abnormal swelling of host tissue.

Heart rot: decay characteristically confined to the heartwood.

Heartwood: the inner layers of wood which, in the growing tree, contain only a few living cells.

Heteroecious: requiring two unrelated host plants to complete its life cycle (cf. autoecious; host-alternating).

Host: a living organism harboring a parasite.

Host-alternating: requiring the production of spore states on two different host species, to complete the life cycle of a heteroecious rust (cf heteroecious).

Hymenium: the spore-bearing layer of a fungus fruit body.

Hymenomycetes: a biological grouping of basidiomycetes that produce spores from a hymenium of exposed basidia, which are often borne on specialized structures such as gills or pores. These fungi are usually large and fleshy, such as mushrooms and conks.

Hyperparasite: an organism that is parasitic on another parasite.
Hyperplasia: plant tissue enlargement, such as brooming or galls, resulting from excessive cell division.
Hypertrophy: symptoms of excessive growth, resulting from abnormal enlargement of plant tissue.
Hypha, pl. **Hyphae:** the basic filamentous vegetative cells of a fungus (cf. mycelium).
Hypodermataceae: a group of ascomycetes, some of which cause needle cast in conifers.
Immunity: having qualities that do not permit infection by a given pathogen.
Imperfect state: see anamorph (syn. asexual state).
Infection court: the place on the host where a pathogen initiates infection.
Inoculum: infectious material of a pathogen.
Lesion: an area of diseased tissue.
Mitosporic fungi – (formerly known as Deuteromycetes) an artificial grouping of conidial fungi whose teleomorphs have not been found or are lacking. The majority are closely related to anamorphs of ascomycetes (molds), and a few are more closely aligned to the basidiomycetes.
Mycelium, pl. **Mycelia:** a mass of fungus hyphae.
Mycelial fan: a typically fan-like mass of hyphae as in Armillaria root rot.
Mycoplasma: similar to bacteria, but smaller and lacking cell walls, and often causing virus-like symptoms.
Mycorrhiza, pl. **Mycorrhizae:** a symbiotic association of a fungus with the root of a tree.
Necrosis: death of cells or tissues.
Necrotic symptoms: symptoms (usually discoloration) produced by the death of plant cells.
Needle blight: fungal disease affecting conifer needles of any age.
Needle cast: a disease resulting in the premature dropping of the needles in coniferous trees. It is frequently associated with infection by certain fungi (Hypodermataceae), but is also caused by non-infectious diseases, usually on needles of current year.
Obligate parasite: an organism that lives only on, and obtains nutrients from, living host tissue.
Oomycetes: a class of microscopic soil and water organisms (**Stramenopiles**) that have a mobile, swimming spore stage (zoospore) and a thick-walled sexual spore (**oospore**).
Parasite: an organism living on or in, and obtaining its nutrients from, another living organism.
Pathogen: a living organism that is capable of causing disease.
Perfect state: see teleomorph.
Periderm: protective layer of bark.
Perithecium, pl. **Perithecia:** flask-like fruit body of ascomycetes, containing asci.
Phenology: the science of the relations between climate (seasons) and biological phenomena such as bud break and flowering.
Phellogen: cork cambium giving rise to the outer bark or periderm.
Phloem: inner bark tissue which functions in the transport of substances produced in the leaves.
Photosynthesis: the production of nutrients in green plants from carbon dioxide and water. The energy for this process is obtained from sunlight acting on chlorophyll.
Pycnidium, pl. **Pycnidia:** a flask-like fungal fruit body, lined inside with conidiophores, and producing conidia (asexual spores).
Red heartwood stain: a pronounced reddish discoloration induced by fungi in the heartwood of conifers.
Resinosis: an abnormal flow of resin or pitch from conifers.
Resistance: ability of an organism to suppress or retard the activity of a pathogen.
Rhizomorph: a thread or cord-like structure made up of hyphae, frequently produced by *Armillaria* spp.
Saprophyte: an organism using dead organic material as food and commonly causing its decay.
Sap rot: a rot occurring in sapwood.
Sapwood: the outer portion of a woody stem, containing the functional xylem, living cells, and food reserves.
Sclerotium, pl. **Sclerotia:** a hard vegetative mass of fungus tissue, resistant to unfavorable conditions.
Secondary fungus: a weak parasite or saprophyte which usually infects only predisposed, weakened, or dead hosts.
Secondary inoculum: inoculum produced during the growing season (contrast with primary inoculum).
Septum, pl. **Septa:** the cross wall in a hypha.
Sexual reproduction: reproduction involving the union of two nuclei.
Sexual state: see teleomorph.
Sign: a visible portion of a pathogen on a diseased host, such as spore masses, mycelia, and fruit body.
Spermagonial state: state in the life cycle of rusts in which spermatia are exuded in a sweet liquid produced from small flask-shaped fruit bodies called **spermagonia**.
Spermatia - spores produced by spermagonia.
Sporangium, pl. **Sporangia:** an organism producing endogenous asexual spores.
Spore: a microscopic fungus propagule, commonly one-celled, but may consist of several cells. Its reproductive function is analagous to a seed.
Stramenopile: a major group of organisms which includes many of the protists, brown algae, diatoms, and Oomycetes, and is characterized by tripartite tubular hairs
Symptom: any reaction of a host to disease.
Systemic infection: a pathogenic infection that has spread internally through its host.
Target canker: a canker surrounded with concentric rings of callus.
Teleomorph: the sexual (i.e. ascospore or basidiospore) form of a fungus.
Telial host: the host on which the uredinial, telial, and basidial states of rusts develop.
Telium, pl. **Telia:** a fungal (rust) structure producing teliospores.
Teliospore: the rust spore that germinates to produce basidia.
Uredinium pl. **Uredinia:** fungal (rust) structure producing urediniospores.
Urediniomycetes: a group of parasitic basidiomycetes (rust fungi) that often produce rusty spore masses on their host. Several spore states and host alternation also characterize these fungi.
Urediniospores: rust spores produced several times over the growing season and capable of re-infecting the same host.
Vegetative state (of a fungus): a growing or food-absorbing mycelial state that precedes the production of spores.
White rot: a wood decay in which the causal fungi break down both cellulose and lignin. Advanced decay residue is white.
Witches' broom: the dense, often malformed and excessive branching of branches or tree crowns caused by pathogens (rusts, dwarf mistletoes) or abiotic agents.
Xylem: the principal strengthening and water-conducting tissue of the stems, roots, and leaves of plants; wood.
Zoospore: mobile swimming spore of an oomycete.

The Pacific Forestry Centre is one of five research centres of the Canadian Forest Service, Natural Resources Canada. Situated in Victoria the Pacific Forestry Centre cooperates with other government agencies, the forestry industry, and educational institutions to promote the wise management of Canada's forest resources. The Pacific Forestry Centre undertakes research in response to the needs of the various managers of the forest resource. The results of this research are distributed in the form of scientific and technical reports and other publications.

Additional Information

Additional copies of this and other Forest Pest Leaflets, as well as additional scientific details and information about identification services, are available by writing to:

Natural Resources Canada
Candian Forest Service
Pacific Forestry Centre
506 West Burnside Road
Victoria, B.C. V8Z 1M5

Phone (250) 363-0600

On-line information is available at: http://www.pfc.cfs.nrcan.gc.ca

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